What do job adverts tell Higher Education about the 'shape' of Biomedical Engineering graduates?

A.E. Ward, B. Baruah, A. Gbadebo, and N.J. Jackson

Engineering Management Group, Department of Electronics, University of York, York, United Kingdom

Abstract— **Higher Education Institutions are required, at least in some Countries, to design their curricula taking into account the needs of relevant industry. Use of Industrial Advisory Committees is a common way of demonstrating this input. This paper explores an additional window to industry needs through the textual analysis of job advertisements. 36 internet published adverts using the "Biomedical Engineering" search phrase were downloaded and textually analysed to identify the mentioned technical skills, generic skills and the adjectives used to describe the required level of proficiency in them. Results of the analysis of these adverts, using qualitative research analysis software starts to reveal a relevant technical skills hierarchy that Higher Education can use to help inform curricular designed for this employment pathway. The analysis of the generic skills reveals those rated important by employers for different levels of jobs, again of potential use to curriculum designers. Finally the results reveal the adjectives used to show the level of ability employers seek of their graduates. Herein lies a significant difference across the supply and demand side of the first employment transition. The difference can be rationally explained but does not help in closing the gap between what Higher Education provides in terms of graduates and what Industry seeks. The paper concludes that dialogue between Industry and Higher Education could usefully focus on the way skills are defined and claims of ability warranted as a means of closing the "Higher Education is not gives us what employers want" claims.**

Keywords— **Skills Analysis, Skills hierarchy, Biomedical Skills, Graduate Skills, Employability.**

I. Introduction

Accredited academic programmes in the UK, in the areas of Electrical, Technology and Computer Science "… must be informed by current industrial practice" [1].

According to the IET 2015 Skills Survey [2] "*61% of industry find that graduates do not meet their "reasonable" expectations*". The greatest skills gaps being in Communication skills, ability to work across interdisciplinary teams, ability to work on own initiative, technical expertise, leadership and management skills, business acumen and practical skills.

The IET 2015 Skills Survey also found that "*28% of the employers reported that content of technical degrees does not meet their needs with 40% believing that courses are not up to date with industry; and 57% believing that courses do not develop practical skills.*" For IET accreditation the department must demonstrate that they seek industrial input throughout the design, development, delivery and review of the academic programmes. A common form of this input is through some form of Industrial Advisory Committee. Experience at the University of York is that it is reasonably easy to engage with staff from large employers as they often have University Liaison personnel or have the resources to enable them to engage with the Department in an active way. We have much greater difficulty in engaging with Small to Medium Sized Enterprises. Given that there are 5,389,450 businesses in the UK at the start of 2015 [3] of which only 6,965 had 250 or more employees, seeking the views of large employers is arguably not fully representative of the world of work. This is clearly a very broad-brush figure; in reality there are significant sectorial and regional variations. No suggestion is made in this paper that existing means of obtaining industrial input to academic programmes are in any way flawed, rather it explores and alternative window to employer needs – through an analysis of job advertisements.

II. METHODOLOGY

45 job advertisements were downloaded from the Internet from a single generic recruitment website [www.jobsite.co.uk]. The search used was "biomedical engineering" and the 45 adverts represent all those live on the search day.

The jobsite site acts as a collator of job descriptions and is not one that requires all job descriptions to follow a common homogeneous format. The sample was thereby considered essentially random in format and content.

A number of the adverts were direct duplicates indicating more than one identical position - these identical duplicates were removed from the sample selected for analysis. Of the 36 remaining jobs reviewed 34 were "permanent", one "full-time" and one unspecific in this aspect.

The text of each job advert was imported as "Internals" to NVivo, a qualitative research analysis software package. The adverts were coded in a number of different ways, by job titles, technical skills, generic skills and adjectives mentioned in the advert text. The coding was essentially seman-

tic with as little interpretation of meaning as could be achieved to minimize the potential for coder bias.

The approach to coding was a grounded theory approach based on the hypothesis that there is a hierarchical structure to skills and that there is a distinction between technical skills and generic skills. It was further based on the hypothesis that the competence level required for any particular skill is described by an adjective of some form.

A hierarchical node structure was then developed with the initial starting set being that used for a previous job advertisement analysis [4]. Matrix coding enquiries were then used to help in the analysis and understanding of the adverts.

III. THE JOB ADVERTS

The range of jobs offered within this sample is fairly broad, by their titles there are 21 Engineering posts, 5 with the Manager title, 2 with the Director title, 2 Scientist roles, 4 Specialist roles, 1 Software tester and 1 Technical Author, these were used as the job categories in the analysis presented herein.

IV. TECHNICAL SKILLS

The job descriptions were reviewed for the requirement in technical skills using, as a starting point the skills hierarchy created in the analysis of job adverts from the Renewable Energies sector. There was limited overlap between the Renewable Energies and the Biomedical Engineering sector.

During coding recognition was given where the statement was a description of background experience required that implied ability in the skill. The skills were first listed randomly and then arranged into a draft hierarchy based on logical top-level category groupings. A matrix-coding query was used to show the occurrences of each technical skill by job category. In total 58 different technical skills were identified. These skills were grouped into 10 top-level categories as show in Table 1 which shows the number of sub-levels in the hierarchy and the total number of unique skills placed within that top-level node and all its sub-nodes. The table shows the breadth of skills mentioned in the adverts.

Table 1 show that Engineering roles are the most specifically defined in terms of technical skills followed by the Scientist and Specialist roles. There was only one each of Software Tester and Technical Author. Manager roles are the least technically defined, perhaps because the manager roles included in this study are mostly Business Development Managers with one Product Manager. The Director positions are back to being more specifically technically focused.

Table 2 shows the number of mentions of technical and generic skills by job category along with the number of adverts in each job category.

Table 1 Top level of the initial technical skills hierarchy

Top level	Sub levels	Total number of skills
Basic Science	0	1
Biomedical Skills	0	24
Chemistry	0	3
Equipment	1	5
Management	0	2
Mathematics	0	4
Product Development and Production Process	0	7
Sales and Marketing	0	1
Service	0	1
Software Design, Development & Testing	2	10

Table 2 Number of mentions of skills by Job Category

Job Category	Adverts	Technical	Generic
Engineer	21	54	33
Manager	5	2	5
Director	2	6	9
Scientist		37	13
Software Tester	1	12	8
Specialist		7	5
Technical Author	1	2	6

The frequency of occurrence of technical skills provides some information about the required content of curricula if HE is to provide employment graduates. It is unsurprising that for Biomedical Engineering jobs that Biomedical skills have the highest number of mentions. It is interesting to note that some understanding of Quality, Regulations and/or Standards relevant to the discipline is also sought. Service is seen in 6 adverts but this reflects the nature of these job adverts, service skills are not normally included in degree level programmes in the UK. This becomes a lot clearer in Table 3, which shows the number of times qualifications are mentioned in the job adverts by job category.

Table 3 shows that all of the service jobs require ONC or HNC qualification, the qualifications in the UK within which servicing equipment might be expected. The sample size which might explain why very few academic qualifications are required in Managerial jobs and an emphasis on

higher-level qualifications for Director positions can be seen.

Table 3 Qualifications mentioned by Job Category

Job Category	ONC	HNC	HND	FCD	SCD	PhD
Director				1	1	2
Engineer	5	5	1	5	1	
Manager			1			
Scientist						2
Software Tester			1	1		
Specialist			3	3	1	
Field Service Engineer	5	4				

V. GENERIC SKILLS

A total of 20 different generic skills were identified across the job adverts. Table 4 shows the mentions that have been coded as generic skills against the Engineer, Manager and Director job categories. Because there is a large difference in the number of adverts in each category the total number of mentions has been normalized to the number of adverts, as shown in the bottom row. This result, in conjunction with the results in Table 2 shows that when specifying jobs employers tend to place more of an emphasis on the generic skills for higher grade jobs. This has been seen in other studies [4].

An obvious challenge in this area is what is a generic skill and what might better described as a personal behavior or attitude, there is no clear consistency in this area at present. The naming of the generic skills here has been informed by the Tuning Methodology [5] and the comparative study of perceptions of students, academics and employers in the EIE-Surveyor Project [6] but it is accepted this is not an exact science.

The generic skills stated as being required by employers in job adverts, as in the case of the technical skills, provides information on what could usefully be included in academic programmes. That said there are some significant challenges in the area of generic skills, not least of which are the inconsistency in definition of their meaning, lack of any robust assessment methods (except in a few exceptions), a lack of means of stating a student's ability in a generic skill and the common argument of lack of time in the curricula. One exception to the lack of robust assessment method is in public speaking where steps are being taken on assessment [7]-[9].

There are examples of programmes where there is an emphasis on the development of generic skills alongside the technical content [10], pedagogies such as Problem Based Learning, Project Based Learning and Curiosity Based Learning are also methods of achieving this.

Table 4 Number of mentions of generic skills by Job Category

Job Category	Engineer	Manager	Director
Ability to get things done			1
Ability to work on own	2		
Analytical skills			1
Commercial Awareness/Acumen	1	1	
Communications	4		2
Customer focused or service	9		1
Entrepreneurial			1
Innovative/Creative	1		
Interpersonal skills	1	2	
Leadership	1		1
Management	1		
Personal Organization	5	1	
Problem solving			1
Team Working	8	1	
Work under pressure			1
Total	33	5	9
Number of adverts in category	21	5	2
Total / Number of adverts	1.6	1	4.5

Lack of clear definition of generic skills is made more difficult by the differences in which competence in them is specified. The following section explores this in the context of the job adverts analysed.

VI. LEVEL OF ABILITY IN GENERIC SKILLS

In the sample of job adverts 25 unique adjectives were identified, as shown in Table 4. These adjectives were variously used in the context of the persons: background; the company; the job; the offered package (salary, benefits, etc.); personal attributes and behaviours; and proficiency (as in the level of ability with reference to a technical or generic skill). The adjectives marked with a * are those which were used in the context of proficiency (they may or may not have also been used in the other contexts). The number of times the adjective was used in the proficiency context is shown in brackets.

To illustrate the way these adjectives are being used consider the following examples, the number in brackets indicates the number of instances across all job adverts:

"Adept" is found once in the job descriptions in relation to proficiency of a skill as in "You will be adept at reading and understanding technical diagrams".

"Basic" is used (3) to indicate the need for foundation level understanding, as in "Basic awareness of the SDLC (software development life-cycle)" and "Basic understanding of the role of a software tester, testing methodologies and tools".

Table 4 Adjectives identified in the sample of job adverts

Adjective	Adjective	Adjective
Adept* (1)	Fantastic	Proficient* (2)
Basic* (2)	Fluent* (3)	Proven* (1)
Effectively* (3)	Generous	Significant
Excellent/ce* (7)	Good* (8)	Solid* (1)
Exciting	Great* (1)	Strong* (24)
Experienced	High* (3)	Technical ability* (1)
Exposure to	Impeccable* (2)	Working with* (1)
Extensive	Outstanding	
Familiarity with* (4)	Passion	

"Effectively" is used in relation to communications/skill (1) as in "Effectively present information to a variety of people, including senior management, groups, and/or board of directors", personal effectiveness (1) as in "organise and prioritise effectively" and team working (1) as in "effectively managing a small team".

"Excellent or excellence" This adjective is used in three ways, firstly, and as one might expect in how the advert sells the role to the potential candidate (3), such as "Excellent opportunity to join a market leading supplier"; secondly in the description of what the job offers the potential applicant, such as "Excellent Opportunities for Career Advancement" (5) or in relation to the remuneration package (17) such as "excellent benefits package"; it is also used as a skills quality indicator (7), as in "Excellent communication skills", "Excellent interpersonal skills", "Excellent knowledge of all relevant regulations" and "Excellent laboratory practical skills particularly in the area of protein".

In Higher Education the student's performance transcript, the statement of their ability in the subjects they have been assessed, defines their overall ability and that in individual topics. The ability of a student to do any specific subject or assessed skill is indicated by either a mark, grade, or in some, less helpful cases, a qualitative descriptor (Excellent, good, etc.). The mark can be either a percentage or mark out of another defined figure. There are many different grading systems around the world including:

- Letter grades (usually A to F with A being top grade), can also have + and - to show finer gradations [11]
- Numerical grades, for example:
  - 10 (Excellent), 9 (Very good) , … 5 (sufficient), 4 (insufficient) .. 1 (academic dishonesty) as in Romania [12]
  - 5 (Excellent), 4 (Good) down to 1 (Very Poor) in Russia [13]
  - 10 (Excellent), 9 (Very good) ... 6 (Sufficient), to 0-5.9 (Insufficient/Failed) in Mexico [14]
- GP or GPA (Grade Point Average) which can be out of 4 (e.g. USA [15]) or 7 (e.g. Chile [16])
- Worded grades, for example:
  - First, upper second, lower second, etc. (e.g. UK [17]);
  - Excellent (85-100%), Very good or Distinct (75-84%), etc. as in Egypt [18];
  - High Distinction (85-100%), Distinction (75-84%) down to Fail (<50%) in some Australian Institutions[19].

In most academic cases a conversion from any statement to an equivalent percentage is usually provided. The percentage being the one measure that has global meaning.

Clearly there is a very great difference in the way the supply and demand sides of the first employment transition specify the level of ability and in part this is justifiable.

VII. DISCUSSION

A number of questions fall out of the above discussions that apply equally to all graduates as they do to Biomedical Engineers, the main subject of this paper. Firstly, is it the academic's role, or that of any other staff member of the HEI to offer advice and guidance on interpreting the statements of need and helping the student demonstrate they meet the essential requirements to at least get them an interview? There is no doubt that calls for help are made by students to academic supervisors, friendly academics and career advisory staff. Given that the employment situations of graduates in general at a short time after graduation is one of the component measures in Higher Education league tables, it is important that students are given good advice in this respect. So academics, as well as the professional careers service staff in the institution need to be able to give informed advice in all aspects of the employment process including that of interpreting the needs of specific job adverts.

Secondly, is it HEI's responsibility to develop ability in the generic skills in students? Many argue that it is outside

the scope of academic programmes and that there is insufficient time available to cover the technical aspects of the programme and that including generic skills development is a step too far. Other HEI's have rethought their pedagogy completely and now employ techniques that simultaneously develop technical and generic skills [20]-[23].

The third big question is how do we assess generic skills and warrant student ability in them in a way that is meaningful to all stakeholders (specifically HEIs and employers)? [8], [24], [25]

Finally, what is the objective of a job advert? It is to sell the company to prospective candidates but also to state the requirements of the job so that the company is not deluged by inappropriate applications. Therein lies a balance, making the advert too specific may mean there are none, or very few individuals who fit the job and hence applications may be low or zero, at the other end of the spectrum, an advert that is open or vague in terms of requirements is likely to attract too many applications. There is also a moral argument wherein if a candidate meets all the essential requirements should they not expect an interview? A negative answer to this would suggest the application reviewer is making some other judgment on the application – an area open to discrimination claims. This then is where the use of adjectives works for the employer – the requirement is stated, for example "Excellent communication skills", but the level qualifier, the adjective, allows applicants to be subjectively 'ranked' in that dimension and a line to be drawn for the number of candidates who can reasonably be taken to the next stage in the selection process.

In this way the adjective approach is possibly a more effective way of specifying a need.

VIII. COMPLIANCE WITH ETHICAL REQUIREMENTS

There are no ethical issues in this research. No individuals are directly involved so there are no data protection issues or matters requiring informed consent.

IX. CONCLUSIONS

In this paper a relatively small sample of job adverts in the general area of Biomedical Engineering have been textually analysed with the objective of extracting the specific and generic skills mentioned in each advert as part of an ongoing activity of exploring skills hierarchies. This type of analysis is argued to be an alternative window into industry needs at, in part, the student first employment transition. It can also inform the skills required for different career progression pathways.

In this study 45 job adverts were downloaded from a single job advertisement website, the adverts being all of those that were returned from a search of "Biomedical Engineering" on the search day. 36 of the adverts were used in the analysis. The NVivo qualitative research software package was used in the analysis and, using it, the text in the adverts was coded for role group, technical skills, generic skills and the adjectives used.

The results show the technical skills required of different types (and hierarchical levels) of jobs, which should be of interest to curriculum designers if their objective is to align curricula to employment areas. The analysis also shows the generic skills valued by employers – this is a more difficult area because skills are currently poorly defined and measurement and warranting ability is challenging.

The way employers define the level of ability required in skills is also very different to that used by academic institutions. Whilst this can be rationalized it does mean the gap between what Higher Education produces and what employers want is weakly correlatable and, given we frequently hear criticism from industry that HE is not producing the correctly 'shaped' graduates for their needs, perhaps there is a clue to the reason in this analysis.

What then can be done to close the gap? One solution lies in the communication between employers and the education system. A shift in discussion to the specifics of what skills mean and how they are measured along with a move to more common use of terminology could be beneficial, especially in the generic skills area.

This paper reports on the early findings of an ongoing project to explore job adverts and it is recognized tat the power of the findings will be greater with an increased number of adverts and adverts from multiple online sources. The intention of the authors is to expand the dataset so that meaningful recommendations for curricula developers can be derived.

Conflict of Interest

The author declares that they have no conflict of interest in the content of this paper.

References

1. "IET Academic Accreditation," 17-Apr-2015. [Online]. Available: www.theiet.org/academics/accreditation/policy-guidance/ahepguide.cfm?type=pdf. [Accessed: 16-Aug-2016].
2. "2015 IET skills survey," 20-Oct-2015. [Online]. Available: http://www.theiet.org/factfiles/education/skills2015-page.cfm. [Accessed: 16-Aug-2016].

3. "STATISTICAL RELEASE," 13-Oct-2015. [Online]. Available: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/467443/bpe_2015_statistical_release.pdf. [Accessed: 16-Aug-2016].
4. A. E. Ward, A. Gbadebo, and B. Baruah, "Using job advertisements to inform curricula design for the key global technical challenges," 2015, pp. 1–6. DOI:10.1109/ITHET.2015.7218042
5. J. Gonzalez and R. Wagenaar, "Tuning Educational Structures in Europe," Universidad de Deusto, Mar. 2003.
6. A. E. Ward, "The Alignment of Generic, Specific and Language Skills within the Electrical and Information Engineering Discipline," EIE-Surveyor Project, York, Dec. 2008.
7. T. Ward, "The Assessment of Public Speaking - a Pan-European view.," presented at the Information Technology based Higher Education and Training, Antalya, Turkey, 2013, pp. 1–2.
8. N. R. Jackson and A. E. Ward, "Assessing Public Speaking, A trial rubric to speed up and standardise feedback," presented at the 13th International Conference on Information Technology based Higher Education and Training (ITHET), York, England, 2014.
9. A. E. Ward, "The issues of certifying public speaking in technical subjects," in Project Work and Internship – Theory and Practice, N. Escudeiro, A. Klucznik-Toro, A. Pawelczyk, M. Carbonaro, S. Nanu, and T. welzer, Eds. The PRAXIS Project, 2013, pp. 199–216.
10. A. E. Ward and N. R. Jackson, "Simultaneous development of management skills and behaviours in taught academic programmes," presented at the 13th International Conference on Information Technology based Higher Education and Training (ITHET), York, England, 2014.
11. "Academic grading in Kenya." Wikipedia. [Accessed: 16-Aug-2016]
12. "Academic grading in Romania." Wikipedia. [Accessed: 16-Aug-2016]
13. "Academic grading in Russia." Wikipedia. [Accessed: 16-Aug-2016]
14. "Academic grading in Mexico." Wikipedia. [Accessed: 16-Aug-2016]
15. J. C. CARPER, "Education in the United States," The Educational Forum, vol. 47, no. 2. Wikipedia, pp. 135–149, 30-Jan-2008.
16. "Academic grading in Chile." Wikipedia. [Accessed: 16-Aug-2016]
17. "Academic grading in the United Kingdom." Wikipedia. [Accessed: 16-Aug-2016]
18. "Academic grading in Egypt." Wikipedia. [Accessed: 16-Aug-2016]
19. "Academic grading in Australia." Wikipedia. [Accessed: 16-Aug-2016]
20. A. Avramenko and A. Avramenko, "Enhancing students' employability through business simulation," Education + Training, vol. 54, no. 5, pp. 355–367, Jun. 2012. DOI: 10.1109/ITHET.2015.7218042
21. B. Sumrongthong, "Curiosity Based Learning," pp. 1–49, Sep. 2009.
22. N. R. Jackson and A. E. Ward, "Curiosity Based Learning: Impact Study in 1st Year Electronics Undergraduates," presented at the 11th International Conference on Information Technology based Higher Education and Training (ITHET), Istanbul, Turkey, 2012.
23. C. Hmelo-Silver, "Problem-based learning: What and how do students learn?," Educational Psychology Review, 2004.
24. B. Clayton, K. Blom, D. Meyers, and A. Bateman, Assessing and certifying generic skills:. National Centre for Vocational Education Research, 252 Kensington Road, Leabrook, South Australia 5068, Australia, 2003.
25. L. M. Schreiber, G. D. Paul, and L. R. Shibley, "The Development and Test of the Public Speaking Competence Rubric," Communication Education, vol. 61, no. 3, pp. 205–233, Jul. 2012. DOI: 10.1080/03634523.2012.670709